"Fuzzy" Thinking Complements LONWORKS

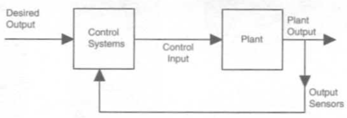
by Harold Rabbie

What has an odd name, offers a simple, practical solution to complex control problems, and works well on LONWORKS networks? Fuzzy logic does all of this, and lets you deal with imprecise measurements like comfort or visibility. By taking a fuzzy approach to designing your LONWORKS network, you can drastically reduce the complexity and cost of your control application.

Fuzzy logic comes to us from U.C. Berkeley, but was popularized in Japan where fuzzy is a common feature in home appliances and electronics. Sales of products based on fuzzy logic reached $1.5 billion in 1990 (according to the Japanese government).

Fuzzy control systems

Here is one way to think about a control system:



For example, a heating, ventilation, and air-conditioning (HVAC) system controls the air temperature in a building (the plant). You set the desired output on a thermostat, for example 20°C (68°F). Sensors measure room temperatures and provide feedback to the control system. From the sensor and setpoint data, the control system determines the signals sent to compressors, fans, baffles, and so on, to reach the desired temperature.

In this example, the system must make decisions based on data that has a high degree of uncertainty. Traditional control systems deal with this uncertainty by using an analytic or experimental model of the plant. But in many cases, the models are hopelessly inaccurate and are subject to uncontrollable disturbances, such as cold weather or the number of people opening doors. Formulating a realistic model of the plant and a stable, accurate control strategy can be difficult and expensive.

Fuzzy logic control systems start with the assumption that the input data is imprecise. The fuzzy control system deals with loosely defined qualities, instead of precise, numerical values. In our example, you really want to control the comfort level in the building, instead of the exact temperature. It is impossible to quantify comfort level precisely. This is where fuzzification saves the day.

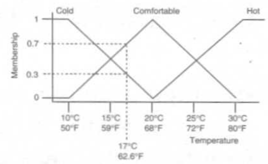
You don't have to hire a Ph.D. in fuzzy thinking. In fact, it is quite simple compared to the chore of developing a theoretical model for your traditional control system. You can easily become an armchair, fuzzy engineer. Read on.

Fuzzification

Fuzzification defines levels by means of membership functions. For example, you can set up three levels: cold, comfortable, and hot. Now assign temperature ranges to these membership functions:

- Anything below 10°C is definitely cold.
- From 10°C and 20°C is either cold or comfortable.
- Anything between 20°C and 30°C is either comfortable or hot.
- Above 30°C you are definitely hot.

The membership functions have values between 0 and 1. Zero means no membership and 1 indicates full membership. Expressing membership functions as straight lines (though these functions can have any shape) gives this graph:



A temperature of 17°C is 30% cold, 70% comfortable, and not at all hot (0%). That, basically, is how fuzzification works.

A Neuron Chip-based temperature sensor can take readings, then fuzzify the data according to membership functions. The sensor node then sends three fuzzy levels over the network in a network variable, for this example, 30%, 70%, and 0%.

Fuzzy logic

A fuzzy control system uses simple logic to make decisions. For example, there are two fuzzy outputs from this control system: `heating` and `air_conditioning`, each with three categories: `off`, `half_on` and `full_on`. Here are examples of fuzzy rules for making decisions:

- IF `room_temperature` is `cold` AND `desired_temperature` is hot, THEN `heating` is `full_on`.
- IF `room_temperature` is `comfortable` AND `desired_temperature` is `cold`, THEN `air_conditioning` is `half_on`.
- IF `room_temperature` is `comfortable` AND `desired_temperature` is `comfortable` THEN `heating` is `off`.

Now you need a few more rules. For example, you can assign the output of an AND rule the lesser of the membership values of the two inputs. If the membership value of `room_temperature` in the cold

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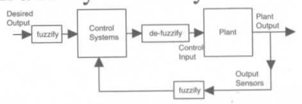
category is 30%, and the membership level of `desired_temperature` in the hot category is 50%, then the first rule, above, would assign a membership of 30% to heating in the `full_on` category. Then you need a similar rule for OR rules, and so on.

A Neuron C programmer can easily write code for this type of rule, for use in LONWORKS nodes.

De-fuzzification

When the fuzzy outputs from the control system arrive as network variables at the plant, Neuron C programs convert fuzzy values into control instructions. This diagram shows the requirements for information processing in a fuzzy control system.



For example, these may be the de-fuzzification rules for an air conditioner:

- A level of `off` means set the compressor motor drive to 0 units.
- A level of `half_on` means set the drive to 20 units.
- A level of `full_on` means set the drive to 40 units.

Suppose that a fuzzy control signal indicates that the air conditioner should be 40% `off`, 60% `half_on`, and 20% `full_on`. This goes to the actuator node as a network variable with three values, 40%, 60%, and 20%. Then the node can use the singleton centroid method to calculate the setting for the air conditioner's actuator:

$$\frac{(0 * 0.4 + 20 * 0.6 + 40 * 0.2)}{(0.4 + 0.6 + 0.2)} = 16.7 \text{ units}$$

This is a simple calculation for the actuator node.

What does fuzzy control get you?

Traditional control systems are computationally intensive, often requiring the solution of complex simultaneous differential equations, with a costly floating point processor. You may also need expensive mathematicians to develop analytical models and control strategies.

On the other hand, fuzzy calculations are easy to implement on the low-cost Neuron Chip. Models are simple. Network variables are ideal for transmitting membership values of 0 to 100%. By storing membership function tables in sensor nodes (as configuration network variables), you can change these tables over the network, at any time, adapting the fuzzy control system to new conditions. And the LonTalk communications protocol built in to every Neuron Chip allows you to to enhance system reliability by distributing a fuzzy control system across the network.

Start to think fuzzy. It may be in your future. ■